10 ESTIMATION OF DISTANCE TO THE ENDPOINT FOR ALTERNATIVE SCENARIOS FOR FLAMMABLE SUBSTANCES

In Chapter 10

- 10.1 Method to estimate the dispersion distance to the LFL for vapor cloud fires.

- 10.2 Method to estimate the distance to the heat radiation endpoint for a pool fire involving a flammable liquid, based on the pool area and factors provided in the appendix.

- 10.3 Method to estimate the distance to the heat radiation endpoint for a fireball from a BLEVE, using a reference table of distances.

- 10.4 Alternative scenario analysis for vapor cloud explosions, using less conservative assumptions than for worst-case vapor cloud explosions.

10.1   Vapor Cloud Fires

The distance to the LFL represents the maximum distance at which the radiant heat effects of a vapor cloud fire might have serious consequences. Exhibit C-2, Appendix C, provides LCL data (in volume percent and milligrams per liter) for listed flammable gases; Exhibit C-3 provides these data for flammable liquids. This guidance provides reference tables for the alternative scenario conditions assumed in this guidance (D stability and wind speed 3.0 meters per second, ground level releases) for estimating the distance to the LCL. Release rate is the primary factor for determining distance to the flammable endpoint. Because the methods used in this guidance assumes that the vapor cloud release is in a steady state and that vapor cloud fires are nearly instantaneous events, release duration is not a critical factor for estimating vapor cloud fire distances. Thus, the reference tables for flammable substances are not broken out separately by release duration (e.g., 10 minutes, 60 minutes). The development of these tables is discussed further in Appendix D, Section D.4. The reference tables for flammable substances (Reference Tables 26-29 at the end of Chapter 10) are listed in Exhibit 6.

To use the reference tables of distances to find the distance to the LFL from the release rate, follow these steps:

- Find the LFL endpoint for the substance in Appendix C (Exhibit C-2 for flammable gases or Exhibit C-3 for flammable liquids).

- Determine from Appendix C whether the table for neutrally buoyant or dense gases and vapors is appropriate (Exhibit C-2 for flammable gases or Exhibit C-3 for flammable liquids). A gas that is lighter than air may behave as a dense gas upon release if it is liquefied under pressure, because the released gas may be mixed with liquid droplets, or if it is cold. Consider the state of the released gas when you decide which table is appropriate.

- Determine whether the table for rural or urban conditions is appropriate.

    -- Use the rural table if your site is in an open area with few obstructions.

    -- Use the urban table if your site is in an urban or obstructed area.

Exhibit 6
Reference Tables of Distances for Vapor Cloud Fires of Flammable Substances

Applicable Conditions			Reference Table Number
Gas or Vapor Density	**Topography**	**Release Duration (minutes)**	
Neutrally buoyant	Rural	10 - 60	26
	Urban	10 - 60	27
Dense	Rural	10 - 60	28
	Urban	10 - 60	29

Neutrally Buoyant Gases or Vapors

- If Exhibit C-2 or C-3 indicates the gas or vapor should be considered neutrally buoyant, and other factors would not cause the gas or vapor to behave as a dense gas, divide the estimated release rate (pounds per minute) by the LFL endpoint (milligrams per liter).

- Find the range of release rate/LFL values that includes your calculated release rate/LFL in the first column of the appropriate table (Reference Table 26 or 27), then find the corresponding distance to the right.

Dense Gases or Vapors

- If Exhibit C-2 or C-3 or consideration of other relevant factors indicates the substance should be considered a dense gas or vapor (heavier than air), find the distance in the appropriate table (Reference Table 28 or 29) as follows:

    -- Find the LFL closest to that of the substance by reading across the top of the table. If the LFL of the substance is halfway between two values on the table, choose the value on the table that is smaller (to the left). Otherwise, choose the closest value to the right or the left.

    -- Find the release rate closest to the release rate estimated for the substance at the left of the table. If the calculated release rate is halfway between two values on the

table, choose the release rate that is larger (farther down on the table). Otherwise, choose the closest value (up or down on the table).

-- Read across from the release rate and down from the LFL to find the distance corresponding to the LFL and release rate for your substance.

Example 27. Flammable Gas Release (Ethylene)

In Example 26, you estimated a release rate for ethylene from a hole in a tank of 3,900 pounds per minute. You want to estimate the distance to the LFL for a vapor cloud fire resulting from this release.

From Exhibit C-2, Appendix C, the LFL for ethylene is 31 mg/L, and the appropriate table for distance estimation is a neutrally buoyant gas table for flammable substances. Your site is in a rural area, so you would use Reference Table 26.

To use the neutrally buoyant gas tables, you need to calculate release rate/endpoint. In this case, release rate/LFL = 3,900/31 or 126. On Reference Table 26, 126 falls in the range of release rate/LFL values corresponding to 0.2 miles.

Example 28. Vapor Cloud Fire from Evaporating Pool of Flammable Liquid

You have a tank containing 20,000 pounds of ethyl ether. A likely scenario for a release might be shearing of a pipe from the tank, with the released liquid forming a pool. You want to estimate the consequences of a vapor cloud fire that might result from evaporation of the pool and ignition of the vapor.

You first need to estimate the rate of release of the liquid from the tank. You can do this using Equation 7-4, Section 7.2.1. For this calculation, you need the area of the hole that would result from shearing the pipe (HA), the height of the liquid in the tank above the hole (LH), and the liquid leak factor (LLF) for ethyl ether, from Exhibit C-3 in Appendix C. The pipe diameter is 2 inches, so the cross sectional area of the hole would be 3.1 square inches. You estimate that the pipe is 2 feet, or 24 inches, below the level of the liquid when the tank is full. The square root of LH (24 inches) is 4.9. LLF for ethyl ether is 34. From Equation 7-4, the rate of release of the liquid from the hole is calculated as:

$$QR_L \quad = \quad 3.1 \times 4.9 \times 34$$
$$= \quad 520 \text{ pounds per minute}$$

You estimate that the release of the liquid could be stopped in about 10 minutes. In 10 minutes, 10×520, or 5,200 pounds, would be released.

The liquid would be released into an area without dikes. To estimate the evaporation rate from the pool formed by the released liquid, you use Equation 7-8 from Section 7.2.3. To carry out the calculation, you need the Liquid Factor Ambient (LFA) and the Density Factor (DF) for ethyl ether. From Exhibit C-3, Appendix C, LFA for ethyl ether is 0.11 and DF is 0.69. The release rate to air is:

$$QR \quad = \quad 5,200 \times 2.4 \times 0.11 \times 0.69$$
$$= \quad 950 \text{ pounds per minute}$$

The evaporation rate from the pool is greater than the estimated liquid release rate; therefore, you use the liquid release rate of 520 pounds per minute as the release rate to air. To estimate the maximum distance at which people in the area of the vapor cloud could suffer serious injury, estimate the distance to the lower flammability limit (LFL) (in milligrams per liter) for ethyl ether, from the appropriate reference table. From Exhibit C-3, Appendix C, LFL for ethyl ether is 57 mg/L, and the appropriate reference table is a dense gas table. Your site is in a rural area with few obstructions, so you use Reference Table 28.

From Reference Table 28, the closest LFL is 60 mg/L. The lowest release rate on the table is 1,500 pounds per minute, which is higher than the evaporation rate estimated for the pool of ethyl ether. For a release rate less than 1,500 pounds per minute, the distance to the LFL is less than 0.1 miles.

10.2   Pool Fires

Pool fires may be considered as potential alternative scenarios for flammable liquids, including gases liquefied by refrigeration alone. You may find, however, that other scenarios will give a greater distance to the endpoint and, therefore, may be more appropriate as alternative scenarios. A "Pool Fire Factor" (PFF) has been derived for each of the regulated flammable liquids and most of the flammable gases to aid in the consequence analysis. The derivation of these factors is discussed in Appendix D, Section D.9. The PFF, listed in Appendix C, Exhibit C-2 for flammable gases and C-3 for flammable liquids, may be used to estimate a distance from the center of a pool fire where people could potentially receive second degree burns from a 40-second exposure. The heat radiation endpoint for this analysis is 5 kilowatts per square meter (kW/m^2). Ambient temperature is assumed to be 25 ºC (77 ºF) for calculation of the PFF for flammable liquids.

To estimate a distance using the PFF, you first need to estimate the size of the pool, in square feet, that might be formed by the release of a flammable substance. You may use the methods described above for toxic liquids to estimate pool size. Density factors (DF) for the estimation of pool size in undiked areas may be found for flammable gases and flammable liquids in Exhibits C-2 and C-3 of Appendix C. For flammable gases, the DF is based on the density at the boiling point. You may want to consider whether the released substance may evaporate too quickly to form a pool of the maximum size, particularly for liquefied gases.

Distances may be estimated from the PFF and the pool area as follows:

$$d \ = \ PFF \ \times \ \sqrt{A} \qquad\qquad \textbf{(10-1)}$$

where: d =   Distance (feet)
   PFF =   Pool Fire Factor (listed for each flammable substance in Appendix C, Exhibits C-2 and C-3)
   A =   Pool area (square feet)

Example 29. Pool Fire of Flammable Liquid

For a tank containing 20,000 pounds of ethyl ether, you want to estimate the consequences of a pool fire. You estimate that 15,000 pounds would be released into an area without dikes, forming a pool. Assuming the liquid spreads to a depth of 1 centimeter (0.39 inches), you estimate the area of the pool formed from Equation 3-6, Section 3.2.3. For this calculation, you need the density factor (DF) for ethyl ether; from Exhibit C-3, Appendix C, DF for ethyl ether is 0.69. From Equation 3-6, the area of the pool is:

$$A = 15,000 \times 0.69 = 10,400 \text{ square feet}$$

You can use Equation 10-1 to estimate the distance from the center of the burning pool where the heat radiation level would reach 5 kW/m^2. For the calculation, you need the square root of the pool area (A) and the pool fire factor (PFF) for ethyl ether. The square root of A, 10,400 square feet, is 102 feet. From Exhibit C-3, Appendix C, PFF for ethyl ether is 4.3. From Equation 10-1, the distance (d) to 5 kW/m^2 is:

$$d = 4.3 \times 102 = 440 \text{ feet (about 0.08 miles)}$$

If you have a gas that is liquefied under pressure or under a combination of pressure and refrigeration, a pool fire is probably not an appropriate alternative scenario. A fire or explosion involving the flammable gas that is released to the air by a sudden release of pressure is likely to have the potential for serious effects at a greater distance than a pool fire (e.g., see the methods for analysis of BLEVEs and vapor cloud explosions in Sections 10.3 and 10.4 below, or see Appendix A for references that provide more information on consequence analysis for fires and explosions).

10.3   BLEVEs

If a fireball from a BLEVE is a potential release scenario at your site, you may use Reference Table 30 to estimate the distance to a potentially harmful radiant heat level. The table shows distances for a range of quantities to the radiant heat level that potentially could cause second degree burns to a person exposed for the duration of the fire. The quantity you use should be the total quantity in a tank that might be involved in a BLEVE. The equations used to derive this table of distances are presented in Appendix D, Section D.10. If you prefer, you may use the equations to estimate a distance for BLEVEs, or you may use a different calculation method or model.

10.4   Vapor Cloud Explosion

If you have the potential at your site for the rapid release of a large quantity of a flammable vapor, particularly into a congested area, a vapor cloud explosion may be an appropriate alternative release scenario. For the consequence analysis, you may use the same methods as for the worst case to estimate consequence distances to an overpressure endpoint of 1 psi (see Section 5.1 and the equation in Appendix C). Instead of assuming the total quantity of flammable substance released is in the vapor cloud, you may estimate a smaller

quantity in the cloud. You could base your estimate of the quantity in the cloud on the release rate estimated as described above for gases and liquids multiplied by the time required to stop the release.

To estimate the quantity in the cloud for a gas liquefied under pressure (not refrigerated), you may use the equation below. This equation incorporates a "flash fraction factor" (FFF), listed in Appendix C, Exhibit C-2 for regulated flammable gases, to estimate the quantity that could be immediately flashed into vapor upon release. A factor of two is included to estimate the quantity that might be carried along as spray or aerosol. See Appendix D, Section D.11 for the derivation of this equation. The equation is:

$$QF = FFF \times QS \times 2 \qquad \textbf{(10-2)}$$

where: QF =   Quantity flashed into vapor plus aerosol (pounds) (cannot be larger than QS)

FFF =   Flash fraction factor (unitless) (listed in Appendix C, Exhibit C-2) (must be less than 1)

QS =   Quantity spilled (pounds)

2   =   Factor to account for spray and aerosol

For derivation of the FFF, the temperature of the stored gas was assumed to be 25 ºC (77 ºF) (except as noted in Exhibit C-2). You may estimate the flash fraction under other conditions using the equation presented in Appendix D, Section D.11.

You may estimate the distance to 1 psi for a vapor cloud explosion from the quantity in the cloud using Reference Table 13 (at the end of the worst-case analysis discussion) or from Equation C-1 in Appendix C. For the alternative scenario analysis, you may use a yield factor of 3 percent, instead of the yield factor of 10 percent used in the worst-case analysis. As discussed in Appendix D, Section D.11, the yield factor of 3 percent is representative of more likely events, based on data from past vapor cloud explosions. If you use the equation in Appendix C, use 0.03 instead of 0.1 in the calculation. If you use Reference Table 13, you can incorporate the lower yield factor by multiplying the distance you read from Reference Table 13 by 0.67.

Example 30. Vapor Cloud Explosion (Propane)

You have a tank containing 50,000 pounds of propane liquefied under pressure at ambient temperature. You want to estimate the consequence distance for a vapor cloud explosion resulting from rupture of the tank.

You use Equation 10-2 to estimate the quantity that might be released to form a cloud. You base the calculation on the entire contents of the tank (QS = 50,000 pounds). From Exhibit C-2 of Appendix C, the Flash Fraction Factor (FFF) for propane is 0.38. From Equation 10-2, the quantity flashed into vapor, plus the quantity that might be carried along as aerosol, (QF) is:

$$QF = 0.38 \times 50,000 \times 2 = 38,000 \text{ pounds}$$

You assume 38,000 pounds of propane is in the flammable part of the vapor cloud. This quantity falls between 20,000 pounds and 50,000 pounds in Reference Table 13; 50,000 pounds is the quantity closest to your quantity. From the table, the distance to 1 psi overpressure is 0.3 mile for 50,000 pounds of propane for a 10 percent yield factor. To change the yield factor to 3 percent, you multiply this distance by 0.67; then the distance becomes 0.2 mile.

Reference Table 14
Neutrally Buoyant Plume Distances to Toxic Endpoint for Release Rate Divided by Endpoint
10-Minute Release, Rural Conditions, D Stability, Wind Speed 3.0 Meters per Second

Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)	Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)
0 - 64	0.1	130,000 - 140,000	4.8
64 - 510	0.2	140,000 - 160,000	5.0
510 - 1,300	0.3	160,000 - 180,000	5.2
1,300 - 2,300	0.4	180,000 - 190,000	5.4
2,300 - 4,100	0.6	190,000 - 210,000	5.6
4,100 - 6,300	0.8	210,000 - 220,000	5.8
6,300 - 8,800	1.0	220,000 - 240,000	6.0
8,800 - 12,000	1.2	240,000 - 261,000	6.2
12,000 - 16,000	1.4	261,000 - 325,000	6.8
16,000 - 19,000	1.6	325,000 - 397,000	7.5
19,000 - 22,000	1.8	397,000 - 477,000	8.1
22,000 - 26,000	2.0	477,000 - 566,000	8.7
26,000 - 30,000	2.2	566,000 - 663,000	9.3
30,000 - 36,000	2.4	663,000 - 769,000	9.9
36,000 - 42,000	2.6	769,000 - 1,010,000	11
42,000 - 47,000	2.8	1,010,000 - 1,280,000	12
47,000 - 54,000	3.0	1,280,000 - 1,600,000	14
54,000 - 60,000	3.2	1,600,000 - 1,950,000	15
60,000 - 70,000	3.4	1,950,000 - 2,340,000	16
70,000 - 78,000	3.6	2,340,000 - 2,770,000	17
78,000 - 87,000	3.8	2,770,000 - 3,240,000	19
87,000 - 97,000	4.0	3,240,000 - 4,590,000	22
97,000 - 110,000	4.2	4,590,000 - 6,190,000	25
110,000 - 120,000	4.4	>6,190,000	>25*
120,000 - 130,000	4.6		

*Report distance as 25 miles

Reference Table 15
Neutrally Buoyant Plume Distances to Toxic Endpoint for Release Rate Divided by Endpoint
60-Minute Release, Rural Conditions, D Stability, Wind Speed 3.0 Meters per Second

Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)	Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)
0 - 79	0.1	100,000 - 108,000	4.8
79 - 630	0.2	108,000 - 113,000	5.0
630 - 1,600	0.3	113,000 - 120,000	5.2
1,600 - 2,800	0.4	120,000 - 126,000	5.4
2,800 - 5,200	0.6	126,000 - 132,000	5.6
5,200 - 7,900	0.8	132,000 - 140,000	5.8
7,900 - 11,000	1.0	140,000 - 150,000	6.0
11,000 - 14,000	1.2	150,000 - 151,000	6.2
14,000 - 19,000	1.4	151,000 - 171,000	6.8
19,000 - 23,000	1.6	171,000 - 191,000	7.5
23,000 - 27,000	1.8	191,000 - 212,000	8.1
27,000 - 32,000	2.0	212,000 - 233,000	8.7
32,000 - 36,000	2.2	233,000 - 256,000	9.3
36,000 - 42,000	2.4	256,000 - 280,000	9.9
42,000 - 47,000	2.6	280,000 - 332,000	11
47,000 - 52,000	2.8	332,000 - 390,000	12
52,000 - 57,000	3.0	390,000 - 456,000	14
57,000 - 61,000	3.2	456,000 - 529,000	15
61,000 - 68,000	3.4	529,000 - 610,000	16
68,000 - 73,000	3.6	610,000 - 699,000	17
73,000 - 79,000	3.8	699,000 - 796,000	19
79,000 - 84,000	4.0	796,000 - 1,080,000	22
84,000 - 91,000	4.2	1,080,000 - 1,410,000	25
91,000 - 97,000	4.4	>1,410,000	>25*
97,000 - 100,000	4.6		

*Report distance as 25 miles

Reference Table 16
Neutrally Buoyant Plume Distances to Toxic Endpoint for Release Rate Divided by Endpoint
10-Minute Release, Urban Conditions, D Stability, Wind Speed 3.0 Meters per Second

Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)	Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)
0 - 160	0.1	600,000 - 660,000	4.8
160 - 1,400	0.2	660,000 - 720,000	5.0
1,400 - 3,600	0.3	720,000 - 810,000	5.2
3,600 - 6,900	0.4	810,000 - 880,000	5.4
6,900 - 13,000	0.6	880,000 - 950,000	5.6
13,000 - 22,000	0.8	950,000 - 1,000,000	5.8
22,000 - 31,000	1.0	1,000,000 - 1,100,000	6.0
31,000 - 42,000	1.2	1,100,000 - 1,220,000	6.2
42,000 - 59,000	1.4	1,220,000 - 1,530,000	6.8
59,000 - 73,000	1.6	1,530,000 - 1,880,000	7.5
73,000 - 88,000	1.8	1,880,000 - 2,280,000	8.1
88,000 - 100,000	2.0	2,280,000 - 2,710,000	8.7
100,000 - 120,000	2.2	2,710,000 - 3,200,000	9.3
120,000 - 150,000	2.4	3,200,000 - 3,730,000	9.9
150,000 - 170,000	2.6	3,730,000 - 4,920,000	11
170,000 - 200,000	2.8	4,920,000 - 6,310,000	12
200,000 - 230,000	3.0	6,310,000 - 7,890,000	14
230,000 - 260,000	3.2	7,890,000 - 9,660,000	15
260,000 - 310,000	3.4	9,660,000 - 11,600,000	16
310,000 - 340,000	3.6	11,600,000 - 13,800,000	17
340,000 - 390,000	3.8	13,800,000 - 16,200,000	19
390,000 - 430,000	4.0	16,200,000 - 23,100,000	22
430,000 - 490,000	4.2	23,100,000 - 31,300,000	25
490,000 - 540,000	4.4	>31,300,000	>25*
540,000 - 600,000	4.6		

*Report distance as 25 miles

Reference Table 17
Neutrally Buoyant Plume Distances to Toxic Endpoint for Release Rate Divided by Endpoint
60-Minute Release, Urban Conditions, D Stability, Wind Speed 3.0 Meters per Second

Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)	Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)
0 - 200	0.1	460,000 - 490,000	4.8
200 - 1,700	0.2	490,000 - 520,000	5.0
1,700 - 4,500	0.3	520,000 - 550,000	5.2
4,500 - 8,600	0.4	550,000 - 580,000	5.4
8,600 - 17,000	0.6	580,000 - 610,000	5.6
17,000 - 27,000	0.8	610,000 - 640,000	5.8
27,000 - 39,000	1.0	640,000 - 680,000	6.0
39,000 - 53,000	1.2	680,000 - 705,000	6.2
53,000 - 73,000	1.4	705,000 - 804,000	6.8
73,000 - 90,000	1.6	804,000 - 905,000	7.5
90,000 - 110,000	1.8	905,000 - 1,010,000	8.1
110,000 - 130,000	2.0	1,010,000 - 1,120,000	8.7
130,000 - 150,000	2.2	1,120,000 - 1,230,000	9.3
150,000 - 170,000	2.4	1,230,000 - 1,350,000	9.9
170,000 - 200,000	2.6	1,350,000 - 1,620,000	11
200,000 - 220,000	2.8	1,620,000 - 1,920,000	12
220,000 - 240,000	3.0	1,920,000 - 2,250,000	14
240,000 - 270,000	3.2	2,250,000 - 2,620,000	15
270,000 - 300,000	3.4	2,620,000 - 3,030,000	16
300,000 - 320,000	3.6	3,030,000 - 3,490,000	17
320,000 - 350,000	3.8	3,490,000 - 3,980,000	19
350,000 - 370,000	4.0	3,980,000 - 5,410,000	22
370,000 - 410,000	4.2	5,410,000 - 7,120,000	25
410,000 - 430,000	4.4	>7,120,000	>25*
430,000 - 460,000	4.6		

*Report distance as 25 miles

Release Rate (lbs/min)	Toxic Endpoint (mg/L)															
	0.0004	0.0007	0.001	0.002	0.0035	0.005	0.0075	0.01	0.02	0.035	0.05	0.075	0.1	0.25	0.5	0.75
	Distance (Miles)															
1	0.6	0.4	0.4	0.2	0.2	0.1	0.1	0.1	<0.1	<0.1	#	#	#	#	#	#
2	0.9	0.6	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.1	<0.1	<0.1	#	#	#	#
5	1.4	1.1	0.9	0.6	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0.1	<0.1	#	#	#
10	2.0	1.5	1.2	0.9	0.6	0.5	0.4	0.4	0.2	0.2	0.1	0.1	0.1	<0.1	<0.1	#
30	3.7	2.7	2.2	1.5	1.1	0.9	0.7	0.7	0.5	0.3	0.3	0.2	0.2	0.1	0.1	<0.1
50	5.0	3.7	3.0	2.1	1.9	1.2	1.0	0.9	0.6	0.4	0.4	0.3	0.2	0.2	0.1	0.1
100	7.4	5.3	4.3	3.0	2.3	1.7	1.4	1.2	0.9	0.6	0.6	0.4	0.4	0.2	0.2	0.1
150	8.7	6.8	5.5	3.8	2.8	2.3	1.9	1.6	1.1	0.8	0.7	0.6	0.5	0.3	0.2	0.2
250	12	8.7	7.4	5.0	3.7	3.0	2.4	2.1	1.4	1.1	0.9	0.7	0.5	0.4	0.3	0.2
500	17	13	11	7.4	5.3	4.5	3.6	3.0	2.1	1.6	1.3	1.1	0.9	0.6	0.4	0.3
750	22	16	13	9.3	6.8	5.6	4.5	3.8	2.7	1.9	1.6	1.3	1.1	0.7	0.5	0.4
1,000	>25	19	16	11	8.1	6.8	5.2	4.5	3.1	2.3	2.2	1.5	1.3	0.8	0.6	0.4
1,500	*	23	19	13	9.9	8.1	6.8	5.6	3.9	2.9	2.4	1.9	1.6	1.0	0.7	0.6
2,000	*	>25	22	15	12	9.3	7.4	6.8	4.5	3.4	2.7	2.2	1.9	1.2	0.8	0.6
2,500	*	*	25	17	13	11	8.7	7.4	5.2	3.8	3.2	2.5	2.1	1.3	0.9	0.7
3,000	*	*	>25	19	14	12	9.3	8.1	5.7	4.2	3.5	2.8	2.4	1.4	1.0	0.8
4,000	*	*	*	22	17	14	11	9.3	6.8	4.9	4.1	3.3	2.8	1.7	1.1	0.9
5,000	*	*	*	>25	19	16	12	11	7.4	5.6	4.7	3.7	3.1	2.1	1.3	1.1
7,500	*	*	*	*	24	19	16	13	9.3	6.8	5.8	4.7	4.0	2.4	1.6	1.3
10,000	*	*	*	*	>25	22	18	16	11	8.1	6.8	5.3	4.6	2.8	1.9	1.5
15,000	*	*	*	*	*	>25	22	19	13	9.9	8.1	6.8	5.7	3.5	2.4	1.9
20,000	*	*	*	*	*	*	>25	22	16	11	9.3	7.4	6.8	4.0	2.8	2.2
50,000	*	*	*	*	*	*	*	>25	24	18	15	12	10	6.5	4.5	3.6
75,000	*	*	*	*	*	*	*	*	>25	22	18	15	13	7.8	5.4	4.4
100,000	*	*	*	*	*	*	*	*	*	>25	21	17	14	8.9	6.3	5.0
150,000	*	*	*	*	*	*	*	*	*	*	>25	20	17	11	7.4	6.0
200,000	*	*	*	*	*	*	*	*	*	*	*	23	19	12	8.5	6.8

* > 25 miles (report distance as 25 miles)   # <0.1 mile (report distance as 0.1 mile)

Reference Table 19
Dense Gas Distances to Toxic Endpoint
60-minute Release, Rural Conditions, D Stability, Wind Speed 3.0 Meters per Second

Release Rate (lbs/min)	Toxic Endpoint (mg/L)															
	0.0004	0.0007	0.001	0.002	0.0035	0.005	0.0075	0.01	0.02	0.035	0.05	0.075	0.1	0.25	0.5	0.75
	Distance (Miles)															
1	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.1	<0.1	#	#	#	#	#	#	#
2	0.8	0.6	0.5	0.3	0.2	0.2	0.2	0.1	0.1	<0.1	<0.1	<0.1	#	#	#	#
5	1.6	1.0	0.8	0.5	0.4	0.3	0.2	0.2	0.2	0.1	0.1	0.1	<0.1	#	#	#
10	2.0	1.4	1.2	0.8	0.6	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.1	<0.1	<0.1	#
30	4.0	2.8	2.2	1.5	1.1	0.9	0.7	0.6	0.4	0.3	0.2	0.2	0.2	0.1	0.1	<0.1
50	5.5	3.9	3.1	2.1	1.5	1.2	1.0	0.8	0.6	0.4	0.3	0.3	0.2	0.1	0.1	0.1
100	8.7	6.1	4.8	3.2	2.2	1.8	1.4	1.2	0.8	0.6	0.5	0.4	0.3	0.2	0.1	0.1
150	12	8.1	6.2	4.1	2.9	2.3	1.8	1.6	1.1	0.7	0.6	0.5	0.4	0.3	0.2	0.1
250	17	11	8.7	5.6	4.0	3.2	2.5	2.1	1.4	1.1	0.9	0.7	0.6	0.4	0.2	0.2
500	>25	19	14	9.3	6.2	5.0	3.9	3.3	2.2	1.6	1.3	1.0	0.9	0.5	0.4	0.3
750	*	25	19	12	8.7	6.8	5.1	4.2	2.8	2.0	1.6	1.3	1.1	0.6	0.4	0.4
1,000	*	>25	24	15	11	8.1	6.1	5.2	3.4	2.4	1.9	1.5	1.3	0.7	0.5	0.4
1,500	*	*	>25	20	14	11	8.1	6.8	4.3	3.0	2.5	1.9	1.7	1.0	0.7	0.5
2,000	*	*	*	24	17	13	9.9	8.1	5.2	3.7	2.9	2.3	1.9	1.2	0.7	0.6
2,500	*	*	*	>25	19	15	12	9.3	6.0	4.3	3.4	2.7	2.2	1.3	0.9	0.7
3,000	*	*	*	*	22	17	13	11	6.8	4.8	3.8	3.0	2.5	1.5	1.0	0.8
4,000	*	*	*	*	>25	21	16	14	8.7	5.8	4.7	3.6	3.0	1.7	1.2	0.9
5,000	*	*	*	*	*	25	19	16	9.9	6.8	5.3	4.1	3.5	2.0	1.4	1.1
7,500	*	*	*	*	*	>25	25	20	13	9.3	6.8	5.4	4.5	2.6	1.7	1.4
10,000	*	*	*	*	*	*	>25	25	16	11	8.7	6.8	5.4	3.1	2.1	1.6
15,000	*	*	*	*	*	*	*	>25	21	14	11	8.7	7.4	4.0	2.6	2.1
20,000	*	*	*	*	*	*	*	*	25	17	14	11	8.7	4.8	3.1	2.5
50,000	*	*	*	*	*	*	*	*	>25	>25	25	19	16	8.8	5.6	4.3
75,000	*	*	*	*	*	*	*	*	*	*	>25	25	20	11	7.3	5.6
100,000	*	*	*	*	*	*	*	*	*	*	*	>25	24	14	9.4	6.8
150,000	*	*	*	*	*	*	*	*	*	*	*	*	>25	17	11	8.7
200,000	*	*	*	*	*	*	*	*	*	*	*	*	*	20	13	10

* > 25 miles (report distance as 25 miles)   # <0.1 mile (report distance as 0.1 mile)

Reference Table 20
Dense Gas Distances to Toxic Endpoint
10-minute Release, Urban Conditions, D Stability, Wind Speed 3.0 Meters per Second

Release Rate (lbs/min)	Toxic Endpoint (mg/L)															
	0.0004	0.0007	0.001	0.002	0.0035	0.005	0.0075	0.01	0.02	0.035	0.05	0.075	0.1	0.25	0.5	0.75
	Distance (Miles)															
1	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.1	<0.1	#	#	#	#	#	#	#
2	0.7	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.1	<0.1	<0.1	#	#	#	#	#
5	1.1	0.8	0.6	0.5	0.3	0.3	0.2	0.2	0.1	0.1	0.1	<0.1	<0.1	#	#	#
10	2.1	1.2	1.0	0.7	0.5	0.4	0.3	0.3	0.2	0.1	0.1	0.1	0.1	<0.1	#	#
30	3.0	2.2	1.9	1.2	0.9	0.8	0.6	0.6	0.4	0.3	0.2	0.2	0.1	0.1	<0.1	#
50	4.1	3.0	2.5	1.6	1.2	1.0	0.8	0.7	0.5	0.3	0.3	0.2	0.2	0.1	0.1	<0.1
100	5.8	4.3	3.5	2.7	1.8	1.4	1.2	1.0	0.7	0.6	0.4	0.4	0.3	0.2	0.1	0.1
150	7.4	5.5	4.5	3.1	2.2	1.9	1.4	1.2	0.9	0.7	0.6	0.4	0.4	0.2	0.2	0.1
250	9.9	7.4	5.8	4.1	3.0	2.5	2.0	1.7	1.1	0.9	0.7	0.6	0.5	0.3	0.2	0.1
500	14	11	8.7	5.9	4.3	3.6	2.9	2.5	1.7	1.2	1.0	0.8	0.7	0.4	0.3	0.2
750	17	13	11	7.4	5.5	4.5	3.6	3.1	2.1	1.6	1.2	1.0	0.9	0.5	0.4	0.3
1,000	20	15	12	8.7	6.2	5.3	4.3	3.5	2.5	1.8	1.5	1.2	1.0	0.6	0.4	0.3
1,500	>25	19	16	11	8.1	6.2	5.2	4.5	3.0	2.2	1.8	1.5	1.2	0.7	0.5	0.4
2,000	*	22	18	12	9.3	7.4	6.2	5.2	3.7	2.7	2.2	1.7	1.4	0.9	0.6	0.5
2,500	*	24	20	14	11	8.7	6.8	6.0	3.8	3.0	2.2	1.9	1.7	1.0	0.7	0.6
3,000	*	>25	22	16	11	9.3	7.4	6.8	4.5	3.3	2.7	2.1	1.9	1.1	0.7	0.6
4,000	*	*	>25	18	14	11	8.7	7.4	5.3	4.0	3.2	2.6	2.1	1.2	0.9	0.7
5,000	*	*	*	20	15	12	9.9	8.7	5.8	4.4	3.6	2.9	2.4	1.4	0.9	0.7
7,500	*	*	*	>25	19	16	12	11	7.4	5.5	4.5	3.6	3.0	1.8	1.2	0.9
10,000	*	*	*	*	22	18	14	12	8.7	6.2	5.2	4.2	3.6	2.1	1.4	1.1
15,000	*	*	*	*	>25	22	18	16	11	8.1	6.8	5.2	4.4	2.6	1.7	1.3
20,000	*	*	*	*	*	>25	20	18	12	9.3	7.4	6.0	5.2	3.0	2.0	1.6
50,000	*	*	*	*	*	*	>25	>25	20	15	12	9.7	8.3	5.0	3.3	2.6
75,000	*	*	*	*	*	*	*	*	25	18	15	12	10	6.1	4.1	3.1
100,000	*	*	*	*	*	*	*	*	>25	21	17	14	12	7.0	4.7	3.7
150,000	*	*	*	*	*	*	*	*	*	>25	21	17	14	8.5	5.7	4.5
200,000	*	*	*	*	*	*	*	*	*	*	24	19	16	9.7	6.5	5.1

* > 25 miles (report distance as 25 miles)   # <0.1 mile (report distance as 0.1 mile)

Reference Table 21
Dense Gas Distances to Toxic Endpoint
60-minute Release, Urban Conditions, D Stability, Wind Speed 3.0 Meters per Second

Release Rate (lbs/min)	Toxic Endpoint (mg/L)															
	0.0004	0.0007	0.001	0.002	0.0035	0.005	0.0075	0.01	0.02	0.035	0.05	0.075	0.1	0.25	0.5	0.75
	Distance (Miles)															
1	0.4	0.3	0.2	0.2	0.1	0.1	0.1	<0.1	#	#	#	#	#	#	#	#
2	0.7	0.5	0.4	0.2	0.2	0.2	0.1	0.1	<0.1	<0.1	#	#	#	#	#	#
5	1.1	0.8	0.7	0.4	0.3	0.2	0.2	0.2	0.1	0.1	<0.1	<0.1	<0.1	#	#	#
10	1.7	1.2	1.0	0.7	0.5	0.4	0.3	0.3	0.2	0.1	0.1	0.1	0.1	<0.1	#	#
30	3.3	2.4	1.9	1.3	0.9	0.7	0.6	0.5	0.3	0.2	0.2	0.2	0.1	0.1	<0.1	#
50	4.7	3.3	2.6	1.7	1.2	1.0	0.8	0.7	0.4	0.3	0.3	0.2	0.2	0.1	0.1	<0.1
100	7.4	5.2	4.1	2.7	1.9	1.5	1.2	1.0	0.7	0.5	0.4	0.3	0.3	0.2	0.1	0.1
150	9.9	6.8	5.3	3.4	2.4	1.9	1.5	1.3	0.9	0.6	0.5	0.4	0.3	0.2	0.1	0.1
250	14	9.3	7.4	4.7	3.4	2.7	2.1	1.7	1.1	0.8	0.7	0.5	0.4	0.3	0.2	0.1
500	22	16	12	7.4	5.2	4.2	3.2	2.7	1.7	1.2	1.0	0.8	0.7	0.4	0.2	0.2
750	>25	20	16	9.9	6.8	5.4	4.2	3.5	2.2	1.6	1.3	1.0	0.9	0.5	0.3	0.3
1,000	*	24	19	12	8.1	6.8	5.0	4.2	2.7	1.8	1.6	1.2	1.0	0.6	0.4	0.3
1,500	*	>25	>25	16	11	8.7	6.8	5.5	3.5	1.9	2.0	1.6	1.3	0.7	0.5	0.4
2,000	*	*	*	19	14	11	8.1	6.8	4.2	3.0	2.2	1.9	1.6	0.9	0.6	0.4
2,500	*	*	*	23	16	12	9.3	7.4	4.9	3.4	2.7	2.1	1.7	1.0	0.6	0.5
3,000	*	*	*	>25	18	14	11	8.7	5.5	3.8	3.0	2.4	2.0	1.1	0.7	0.6
4,000	*	*	*	*	22	17	13	11	6.8	4.7	3.1	2.8	2.4	1.3	0.9	0.7
5,000	*	*	*	*	>25	20	16	12	8.1	5.3	4.3	3.3	2.7	1.5	1.0	0.7
7,500	*	*	*	*	*	25	20	17	11	6.8	5.6	4.3	3.5	2.0	1.2	0.9
10,000	*	*	*	*	*	>25	24	20	13	8.7	6.8	5.2	4.3	2.4	1.5	1.1
15,000	*	*	*	*	*	*	>25	>25	17	11	8.7	6.8	5.6	3.0	1.9	1.5
20,000	*	*	*	*	*	*	*	*	20	14	11	8.1	6.8	3.6	2.3	1.7
50,000	*	*	*	*	*	*	*	*	>25	>25	20	15	13	6.6	4.0	3.1
75,000	*	*	*	*	*	*	*	*	*	*	>25	20	16	8.7	5.3	3.9
100,000	*	*	*	*	*	*	*	*	*	*	*	24	20	10	6.3	4.7
150,000	*	*	*	*	*	*	*	*	*	*	*	>25	>25	14	8.2	6.1
200,000	*	*	*	*	*	*	*	*	*	*	*	*	*	16	9.9	7.3

* > 25 miles (report distance as 25 miles)   # <0.1 mile (report distance as 0.1 mile)

Reference Table 22
Distances to Toxic Endpoint for Anhydrous Ammonia Liquefied Under Pressure
D Stability, Wind Speed 3.0 Meters per Second

Release Rate (lbs/min)	Distance to Endpoint (miles)		Release Rate (lbs/min)	Distance to Endpoint (miles)	
	Rural	Urban		Rural	Urban
<10	<0.1*		900	0.6	0.2
10	0.1		1,000	0.6	0.2
15	0.1		1,500	0.7	0.3
20	0.1	<0.1*	2,000	0.8	0.3
30	0.1		2,500	0.9	0.3
40	0.1		3,000	1.0	0.4
50	0.1		4,000	1.2	0.4
60	0.2	0.1	5,000	1.3	0.5
70	0.2	0.1	7,500	1.6	0.5
80	0.2	0.1	10,000	1.8	0.6
90	0.2	0.1	15,000	2.2	0.7
100	0.2	0.1	20,000	2.5	0.8
150	0.2	0.1	25,000	2.8	0.9
200	0.3	0.1	30,000	3.1	1.0
250	0.3	0.1	40,000	3.5	1.1
300	0.3	0.1	50,000	3.9	1.2
400	0.4	0.2	75,000	4.8	1.4
500	0.4	0.2	100,000	5.4	1.6
600	0.5	0.2	150,000	6.6	1.9
700	0.5	0.2	200,000	7.6	2.1
750	0.5	0.2	250,000	8.4	2.3
800	0.5	0.2			

* Report distance as 0.1 mile

Reference Table 23
**Distances to Toxic Endpoint for Non-liquefied Ammonia, Ammonia Liquefied by Refrigeration, or
Aqueous Ammonia
D Stability, Wind Speed 3.0 Meters per Second**

Release Rate (lbs/min)	Distance to Endpoint (miles)		Release Rate (lbs/min)	Distance to Endpoint (miles)	
	Rural	Urban		Rural	Urban
<8	<0.1*		800	0.7	0.2
8	0.1		900	0.7	0.3
10	0.1		1,000	0.8	0.3
15	0.1	<0.1*	1,500	1.0	0.4
20	0.1		2,000	1.2	0.4
30	0.1		2,500	1.2	0.4
40	0.1		3,000	1.5	0.5
50	0.2	0.1	4,000	1.8	0.6
60	0.2	0.1	5,000	2.0	0.7
70	0.2	0.1	7,500	2.2	0.7
80	0.2	0.1	10,000	2.5	0.8
90	0.2	0.1	15,000	3.1	1.0
100	0.2	0.1	20,000	3.6	1.2
150	0.3	0.1	25,000	4.1	1.3
200	0.3	0.1	30,000	4.4	1.4
250	0.4	0.2	40,000	5.1	1.6
300	0.4	0.2	50,000	5.8	1.8
400	0.4	0.2	75,000	7.1	2.2
500	0.5	0.2	100,000	8.2	2.5
600	0.6	0.2	150,000	10	3.1
700	0.6	0.2	200,000	12	3.5
750	0.6	0.2			

* Report distance as 0.1 mile

Reference Table 24
Distances to Toxic Endpoint for Chlorine
D Stability, Wind Speed 3.0 Meters per Second

Release Rate (lbs/min)	Distance to Endpoint (miles)		Release Rate (lbs/min)	Distance to Endpoint (miles)	
	Rural	Urban		Rural	Urban
1	<0.1*	<0.1*	750	1.2	0.4
2	0.1		800	1.2	0.5
5	0.1		900	1.2	0.5
10	0.2	0.1	1,000	1.3	0.5
15	0.2	0.1	1,500	1.6	0.6
20	0.2	0.1	2,000	1.8	0.6
30	0.3	0.1	2,500	2.0	0.7
40	0.3	0.1	3,000	2.2	0.8
50	0.3	0.1	4,000	2.5	0.8
60	0.4	0.2	5,000	2.8	0.9
70	0.4	0.2	7,500	3.4	1.2
80	0.4	0.2	10,000	3.9	1.3
90	0.4	0.2	15,000	4.6	1.6
100	0.5	0.2	20,000	5.3	1.8
150	0.6	0.2	25,000	5.9	2.0
200	0.6	0.3	30,000	6.4	2.1
250	0.7	0.3	40,000	7.3	2.4
300	0.8	0.3	50,000	8.1	2.7
400	0.8	0.4	75,000	9.8	3.2
500	1.0	0.4	100,000	11	3.6
600	1.0	0.4	150,000	13	4.2
700	1.1	0.4	200,000	15	4.8

* Report distance as 0.1 mile

Reference Table 25
Distances to Toxic Endpoint for Sulfur Dioxide
D Stability, Wind Speed 3.0 Meters per Second

Release Rate (lbs/min)	Distance to Endpoint (miles)		Release Rate (lbs/min)	Distance to Endpoint (miles)	
	Rural	Urban		Rural	Urban
1	<0.1*	<0.1*	750	1.3	0.5
2	0.1		800	1.3	0.5
5	0.1		900	1.4	0.5
10	0.2	0.1	1,000	1.5	0.5
15	0.2	0.1	1,500	1.9	0.6
20	0.2	0.1	2,000	2.2	0.7
30	0.2	0.1	2,500	2.3	0.8
40	0.3	0.1	3,000	2.7	0.8
50	0.3	0.1	4,000	3.1	1.0
60	0.4	0.2	5,000	3.3	1.1
70	0.4	0.2	7,500	4.0	1.3
80	0.4	0.2	10,000	4.6	1.4
90	0.4	0.2	15,000	5.6	1.7
100	0.5	0.2	20,000	6.5	1.9
150	0.6	0.2	25,000	7.3	2.1
200	0.6	0.2	30,000	8.0	2.3
250	0.7	0.3	40,000	9.2	2.6
300	0.8	0.3	50,000	10	2.9
400	0.9	0.4	75,000	13	3.5
500	1.0	0.4	100,000	14	4.0
600	1.1	0.4	150,000	18	4.7
700	1.2	0.4	200,000	20	5.4

* Report distance as 0.1 mile

Reference Table 26
Neutrally Buoyant Plume Distances to Lower Flammability Limit (LFL)
For Release Rate Divided by LFL
Rural Conditions, D Stability, Wind Speed 3.0 Meters per Second

Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)	Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)
0 - 28	0.1	2,700 - 3,300	0.9
28 - 40	0.1	3,300 - 3,900	1.0
40 - 60	0.1	3,900 - 4,500	1.1
60 - 220	0.2	4,500 - 5,200	1.2
220 - 530	0.3	5,200 - 5,800	1.3
530 - 860	0.4	5,800 - 6,800	1.4
860 - 1,300	0.5	6,800 - 8,200	1.6
1,300 - 1,700	0.6	8,200 - 9,700	1.8
1,700 - 2,200	0.7	9,700 - 11,000	2.0
2,200 - 2,700	0.8	11,000 - 13,000	2.2

Reference Table 27
Neutrally Buoyant Plume Distances to Lower Flammability Limit (LFL)
For Release Rate Divided by LFL
Urban Conditions, D Stability, Wind Speed 3.0 Meters per Second

Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)	Release Rate/Endpoint [(lbs/min)/(mg/L)]	Distance to Endpoint (miles)
0 - 68	0.1	5,500 - 7,300	0.7
68 - 100	0.1	7,300 - 9,200	0.8
100 - 150	0.1	9,200 - 11,000	0.9
150 - 710	0.2	11,000 - 14,000	1.0
710 - 1,500	0.3	14,000 - 18,000	1.2
1,500 - 2,600	0.4	18,000 - 26,000	1.4
2,600 - 4,000	0.5	26,000 - 31,000	1.6
4,000 - 5,500	0.6	31,000 - 38,000	1.8

Reference Table 28
Dense Gas Distances to Lower Flammability Limit
Rural Conditions, D Stability, Wind Speed 3.0 Meters per Second

Release Rate (lbs/min)	Lower Flammability Limit (mg/L)									
	27	30	35	40	45	50	60	70	100	>100
	Distance (Miles)									
<1,500	#	#	#	#	#	#	#	#	#	#
1,500	<0.1	<0.1	#	#	#	#	#	#	#	#
2,000	0.1	0.1	<0.1	#	#	#	#	#	#	#
2,500	0.1	0.1	0.1	<0.1	#	#	#	#	#	#
3,000	0.1	0.1	0.1	0.1	<0.1	<0.1	#	#	#	#
4,000	0.1	0.1	0.1	0.1	0.1	0.1	<0.1	#	#	#
5,000	0.1	0.1	0.1	0.1	0.1	0.1	0.1	<0.1	#	#
7,500	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	<0.1	#
10,000	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	<0.1

\# < 0.1 mile (report distance as 0.1 mile)

Reference Table 29
Dense Gas Distances to Lower Flammability Limit
Urban Conditions, D Stability, Wind Speed 3.0 Meters per Second

Release Rate (lbs/min)	Lower Flammability Limit (mg/L)				
	27	30	35	40	>40
	Distance (Miles)				
<5,000	#	#	#	#	#
5,000	<0.1	<0.1	#	#	#
7,500	0.1	0.1	<0.1	#	#
10,000	0.1	0.1	0.1	<0.1	#

\# < 0.1 mile (report distance as 0.1 mile)

Reference Table 30
Distance to Radiant Heat Dose at Potential Second Degree Burn Threshold Assuming Exposure for Duration of Fireball from BLEVE
(Dose = [5 kW/m²]$^{4/3}$ x Exposure Time)

Quantity in Fireball (pounds)		1,000	5,000	10,000	20,000	30,000	50,000	75,000	100,000	200,000	300,000	500,000
Duration of Fireball (seconds)		3.5	5.9	7.5	9.4	10.8	12.7	14.8	15.5	17.4	18.7	20.3
CAS No.	Chemical Name	Distance (miles) at which Exposure for Duration of Fireball May Cause Second Degree Burns										
75-07-0	Acetaldehyde	0.04	0.08	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6
74-86-2	Acetylene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
598-73-2	Bromotrifluoroethylene	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.1	0.1	0.2
106-99-0	1,3-Butadiene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
106-97-8	Butane	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
106-98-9	1-Butene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
107-01-7	2-Butene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
25167-67-3	Butene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
590-18-1	2-Butene-cis	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
624-64-6	2-Butene-trans	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
463-58-1	Carbon oxysulfide	0.02	0.05	0.06	0.09	0.1	0.1	0.2	0.2	0.2	0.3	0.3
7791-21-1	Chlorine monoxide	0.01	0.02	0.02	0.03	0.03	0.04	0.05	0.06	0.08	0.09	0.1
557-98-2	2-Chloropropylene	0.03	0.07	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.4	0.5
590-21-6	1-Chloropropylene	0.03	0.07	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.4	0.5
460-19-5	Cyanogen	0.03	0.07	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.4	0.5
75-19-4	Cyclopropane	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
4109-96-0	Dichlorosilane	0.02	0.04	0.06	0.08	0.1	0.1	0.2	0.2	0.2	0.3	0.3
75-37-6	Difluoroethane	0.02	0.05	0.07	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4
124-40-3	Dimethylamine	0.04	0.09	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.7
463-82-1	2,2-Dimethylpropane	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
74-84-0	Ethane	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
107-00-6	Ethyl acetylene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8

Quantity in Fireball (pounds)		1,000	5,000	10,000	20,000	30,000	50,000	75,000	100,000	200,000	300,000	500,000
Duration of Fireball (seconds)		3.5	5.9	7.5	9.4	10.8	12.7	14.8	15.5	17.4	18.7	20.3
CAS No.	Chemical Name	Distance (miles) at which Exposure for Duration of Fireball May Cause Second Degree Burns										
75-04-7	Ethylamine	0.04	0.09	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.7
75-00-3	Ethyl chloride	0.03	0.07	0.09	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5
74-85-1	Ethylene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
60-29-7	Ethyl ether	0.04	0.09	0.1	0.2	0.2	0.2	0.3	0.3	0.5	0.5	0.7
75-08-1	Ethyl mercaptan	0.04	0.08	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.6
109-95-5	Ethyl nitrite	0.03	0.06	0.09	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5
1333-74-0	Hydrogen	0.08	0.2	0.2	0.3	0.4	0.5	0.6	0.6	0.9	1.0	1.2
75-28-5	Isobutane	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
78-78-4	Isopentane	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
78-79-5	Isoprene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7
75-31-0	Isopropylamine	0.04	0.09	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.7
75-29-6	Isopropyl chloride	0.04	0.07	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5
74-82-8	Methane	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.6	0.6	0.8
74-89-5	Methylamine	0.04	0.08	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.6
563-45-1	3-Methyl-1-butene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
563-46-2	2-Methyl-1-butene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7
115-10-6	Methyl ether	0.04	0.08	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.6
107-31-3	Methyl formate	0.03	0.06	0.08	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.4
115-11-7	2-Methylpropene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
504-60-9	1,3-Pentadiene	0.05	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.7
109-66-0	Pentane	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
109-67-1	1-Pentene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
646-04-8	2-Pentene, (E)-	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8

Quantity in Fireball (pounds)		1,000	5,000	10,000	20,000	30,000	50,000	75,000	100,000	200,000	300,000	500,000
Duration of Fireball (seconds)		3.5	5.9	7.5	9.4	10.8	12.7	14.8	15.5	17.4	18.7	20.3
CAS No.	Chemical Name	Distance (miles) at which Exposure for Duration of Fireball May Cause Second Degree Burns										
627-20-3	2-Pentene, (Z)-	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
463-49-0	Propadiene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
74-98-6	Propane	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
115-07-1	Propylene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
74-99-7	Propyne	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
7803-62-5	Silane	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7
116-14-3	Tetrafluoroethylene	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.07	0.09	0.1	0.1
75-76-3	Tetramethylsilane	0.05	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.7
10025-78-2	Trichlorosilane	0.01	0.03	0.04	0.06	0.07	0.08	0.1	0.1	0.2	0.2	0.2
79-38-9	Trifluorochloroethylene	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.1	0.1	0.2
75-50-3	Trimethylamine	0.04	0.09	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.7
689-97-4	Vinyl acetylene	0.05	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8
75-01-4	Vinyl chloride	0.03	0.07	0.09	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5
109-92-2	Vinyl ethyl ether	0.04	0.09	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.6
75-02-5	Vinyl fluoride	0.01	0.02	0.03	0.04	0.05	0.06	0.08	0.09	0.1	0.1	0.2
75-35-4	Vinylidene chloride	0.02	0.05	0.07	0.09	0.1	0.1	0.2	0.2	0.3	0.3	0.4
75-38-7	Vinylidene fluoride	0.02	0.05	0.07	0.09	0.1	0.1	0.2	0.2	0.3	0.3	0.4
107-25-5	Vinyl methyl ether	0.04	0.08	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.6